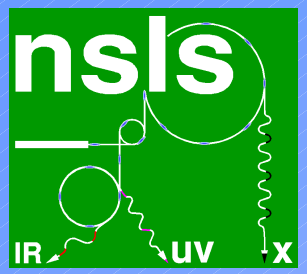


NATIONAL SYNCHROTRON LIGHT SOURCE

Simulation of Instabilities in Stretched Bunches

N. Towne

September 20, 2000

Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN NATIONAL LABORATORY

Outline

- Computer code for integration of the Vlasov-Fokker-Planck equation
- Simulations of instabilities
  - **microwave instability with broad-band Q=1 resonator impedance**
  - **instability driven by inductively detuned main- and hom-rf modes**
  - **equilibrium-phase instability driven by the main rf mode**
  - **beam response functions**
  - **slave bunches to gauge coherence of multiple bunches**

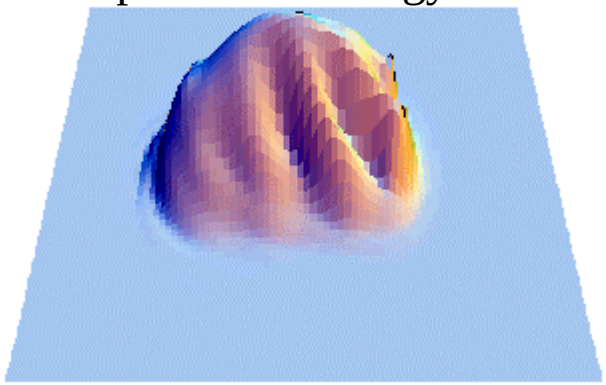
The computer code

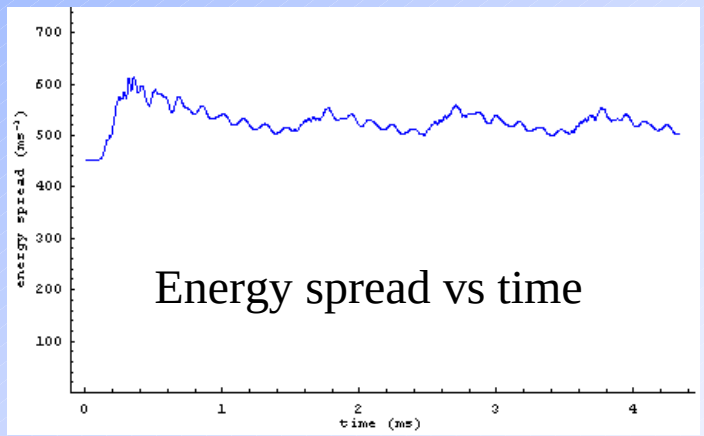
- Integration of Vlasov-Fokker-Planck equation - follows Warnock's methods (SLAC-PUB-8404) with minor changes
- Potential well distortion incorporated into the symplectic map *M* for the time step
- Arbitrary rf potentials allowed
- Broadband and high-Q impedances
- Rudimentary feedback for high-Q impedances
- Movies of bunch motion assembled later
- Written in Mathematica

Microwave instability

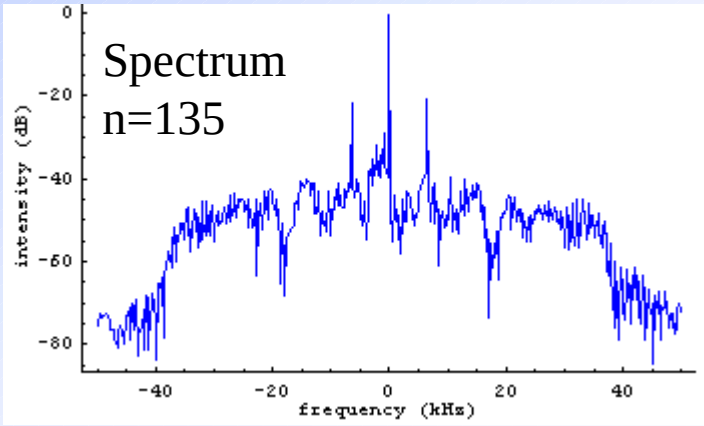
280 mA, fully stretched
Broad-band impedance only

Bunch intensity vs
phase and energy





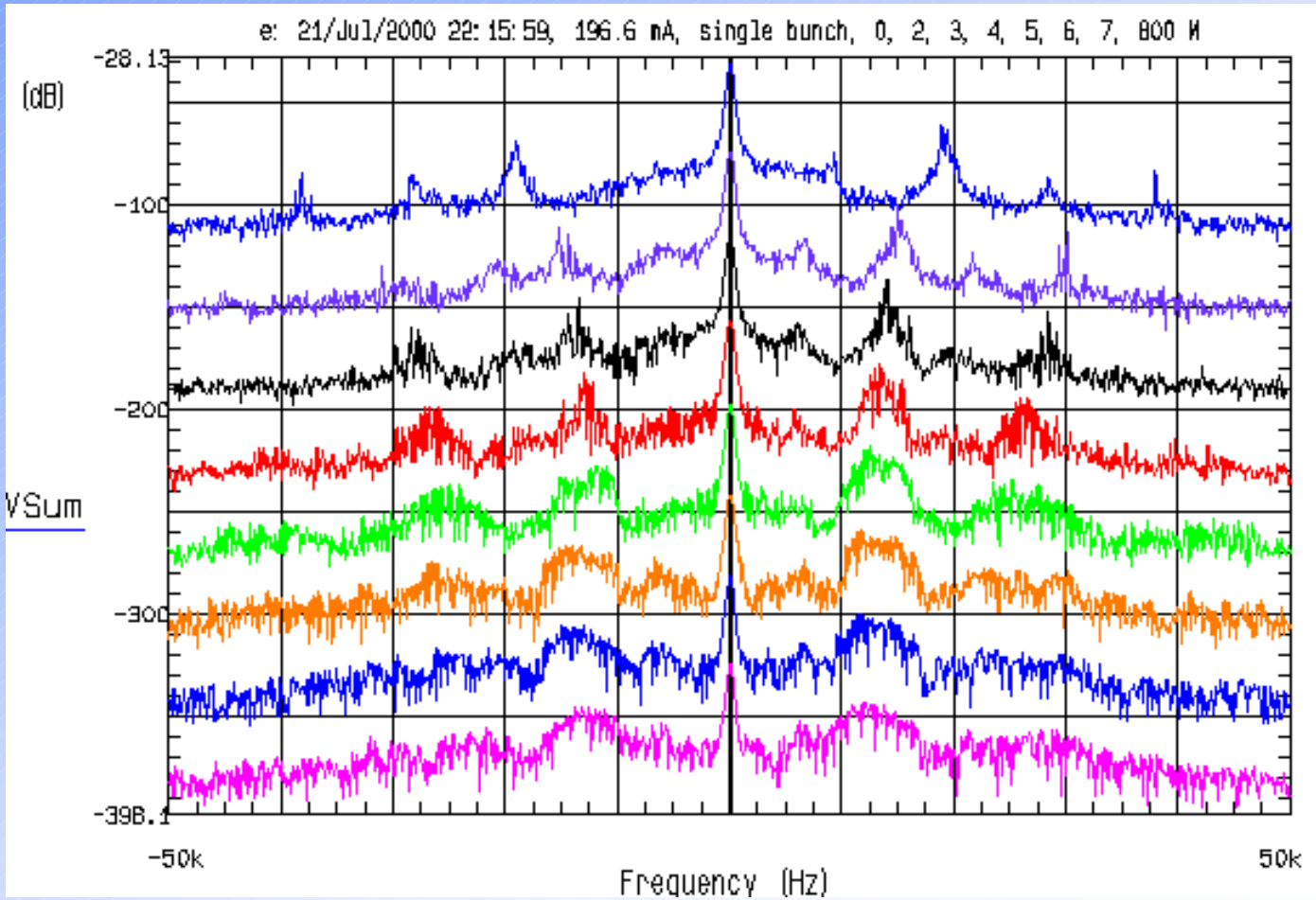
Energy spread vs time



Spectrum
n=135

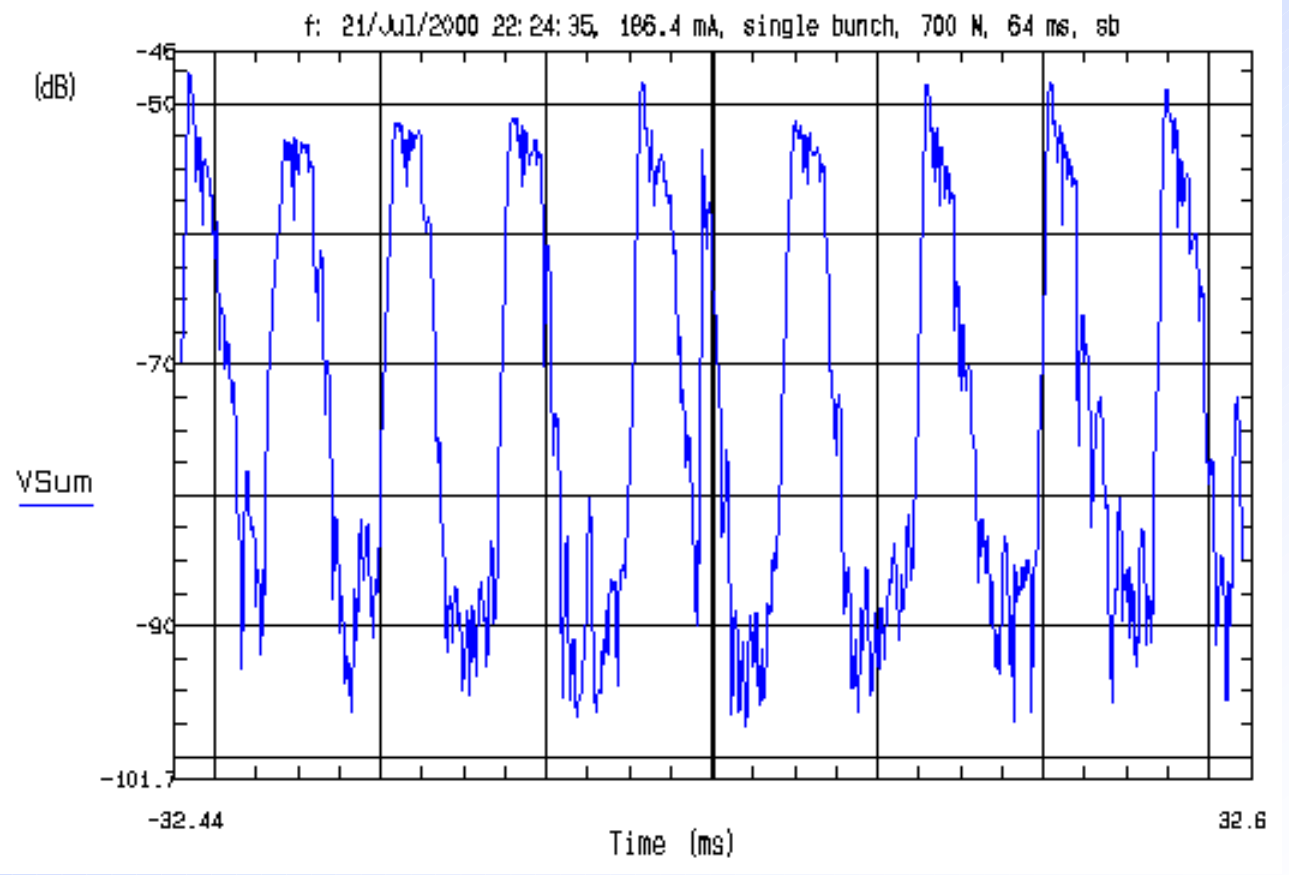
Measured spectra of a progressively stretched bunch

- Quadrupole mode at low hhc field
- Stretched bunch has broadened lines 10-15 kHz offset
- When more intense, broadened lines fill spectrum

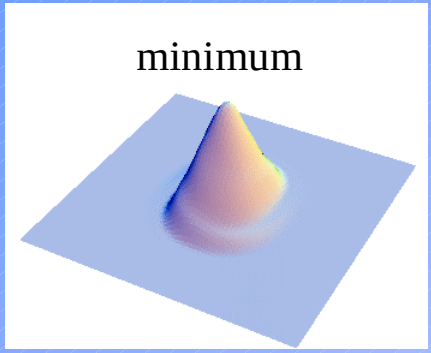


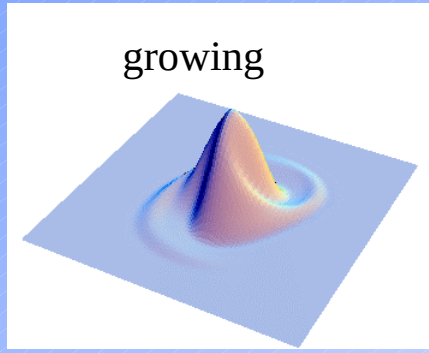
Relaxation in a stretched bunch in the VUV-ring

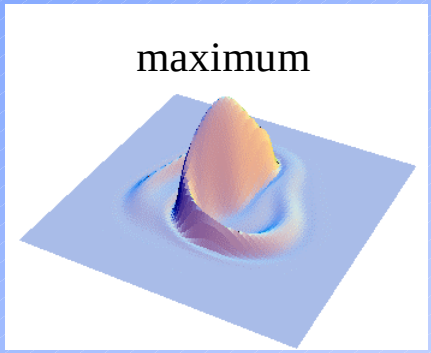
- Spectrum with zero span centered on a broadened line (previous slide)
- RBW 3 kHz
- VUV damping time 7 ms and unstretched synchrotron frequency 11 kHz

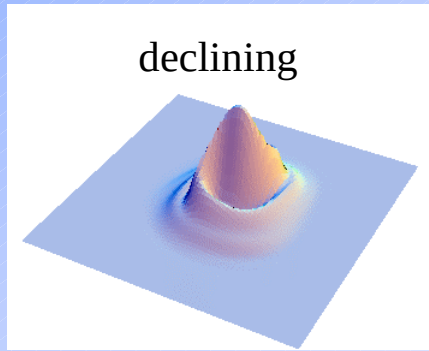


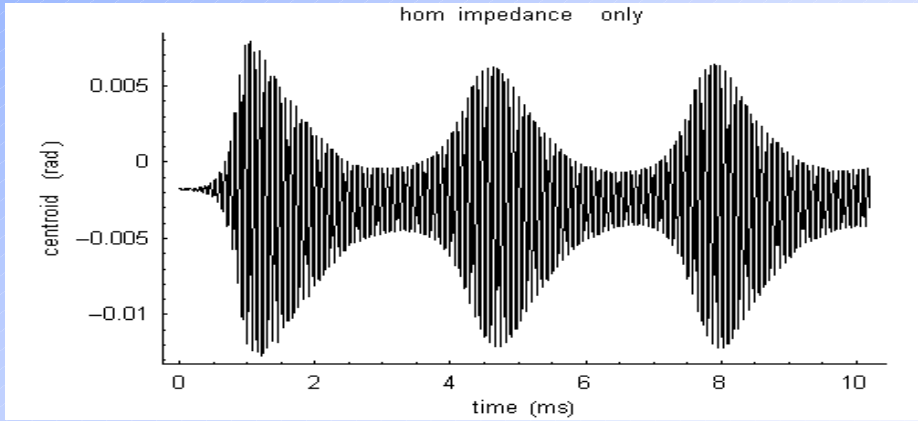
Inductively detuned hom rf mode – partially stretched

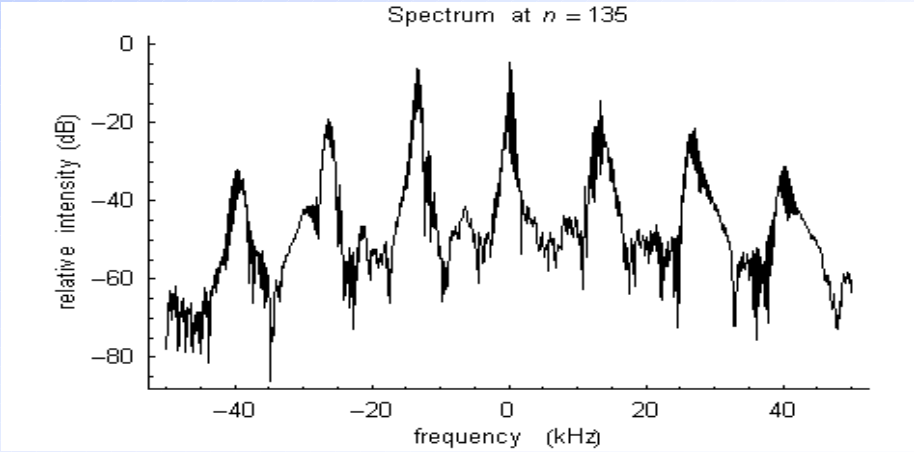








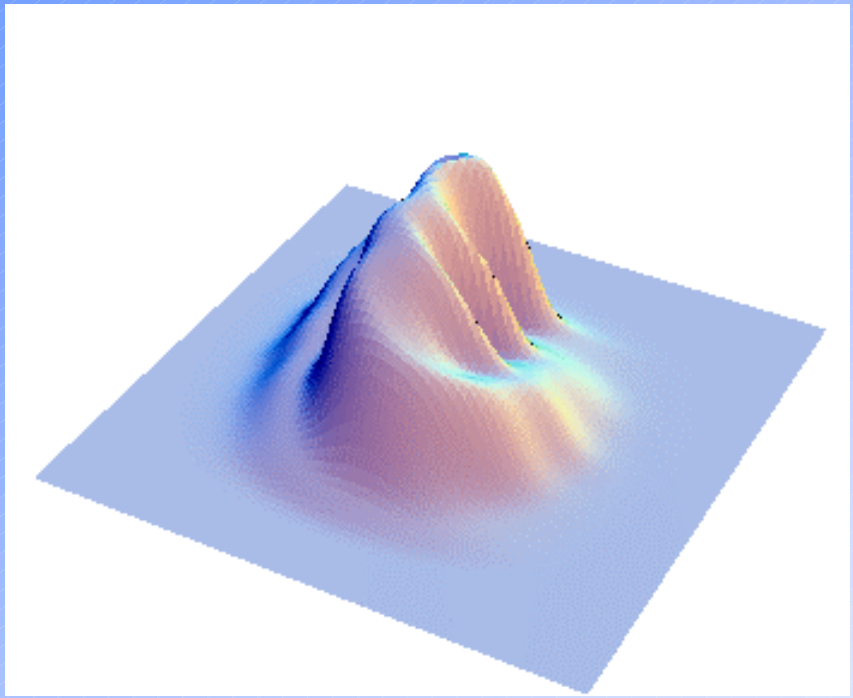


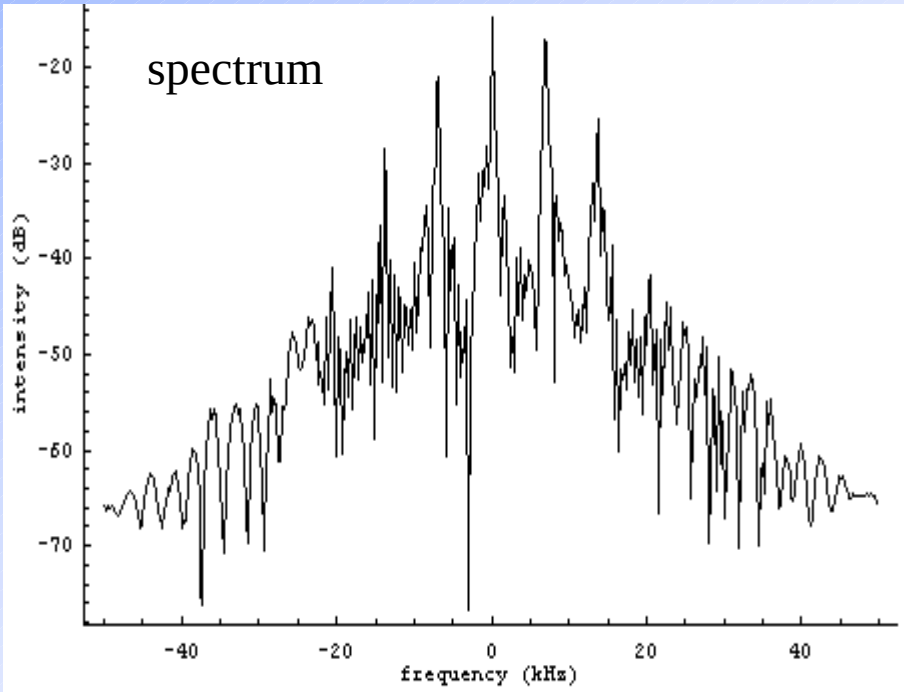


Simulation with >80% nominal hhc voltage showing quadrupole-mode character of instability

Both broad-band impedance and hom simulation

300 mA

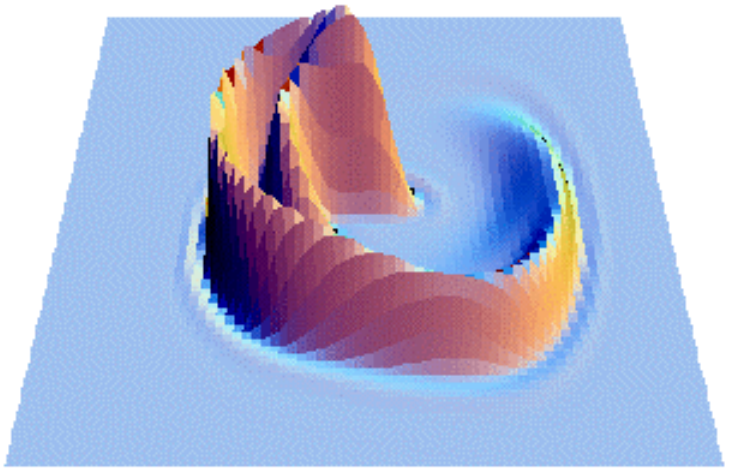




Inductively detuned main rf mode

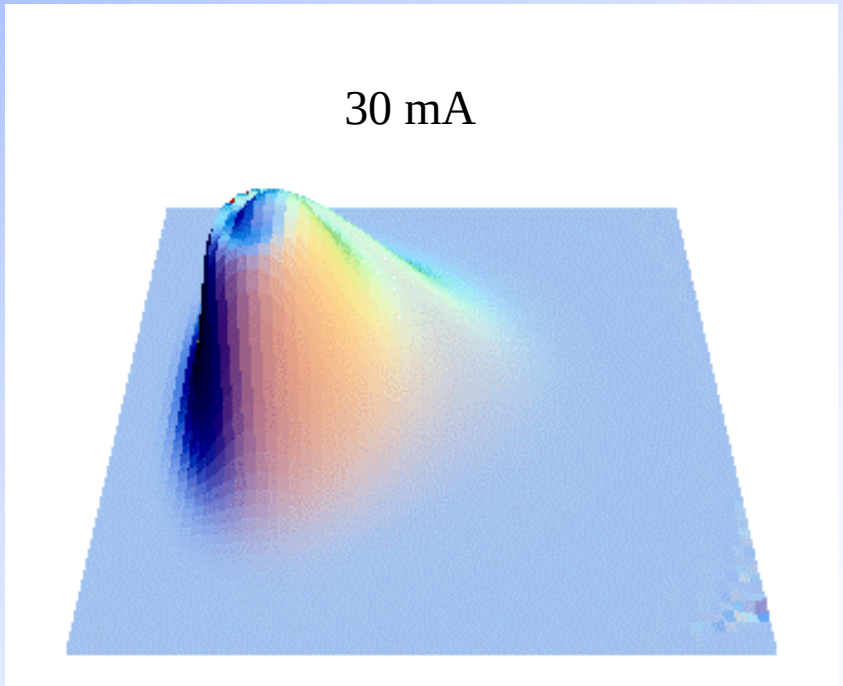
- Instability driven by an inductively detuned (Robinson unstable) main rf mode
- Complicated folding of bunch
- Typically grows until off the grid – not known if relaxation or beam loss occurs

Stretched
30 mA



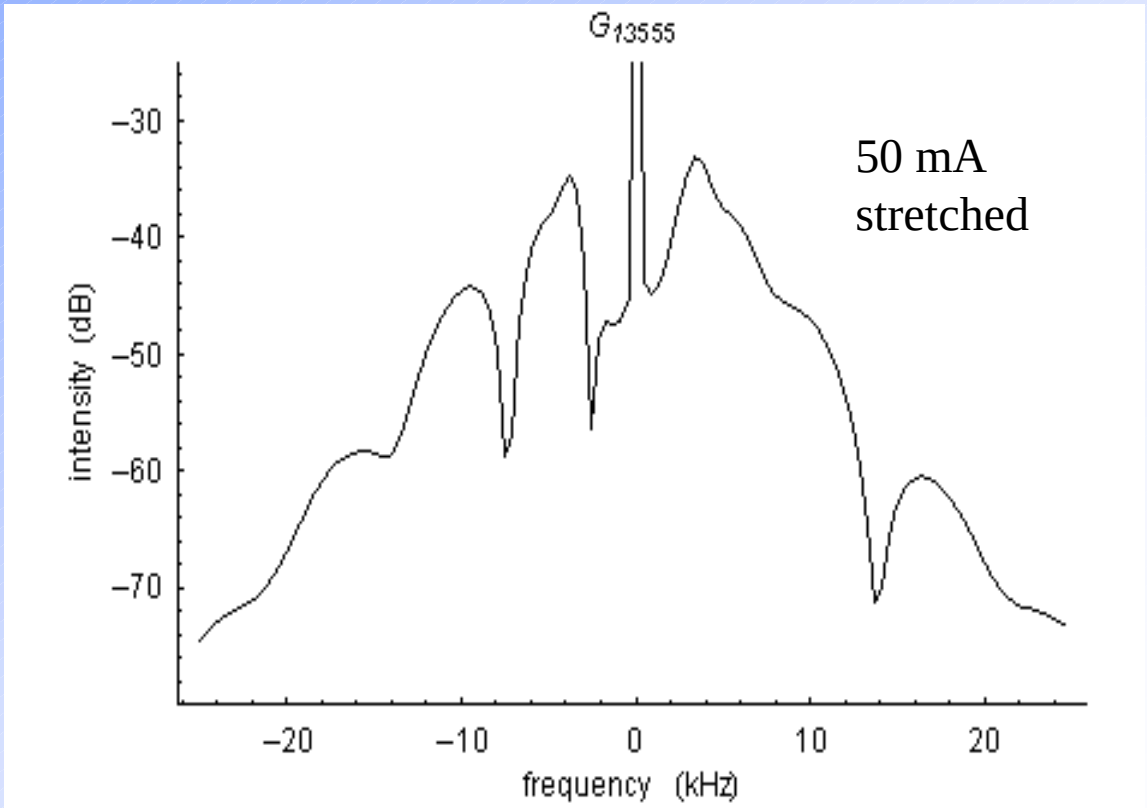
Equilibrium-phase instability driven by the main rf mode

- Capacitively detuned (Robinson-stable) main rf mode impedance.
- Above a threshold current, the Haissinski distribution is unstable (Miyahara et al. 1983). The beam relaxes to one of two stable distributions.
- At higher current, distribution typically evolves off the grid.



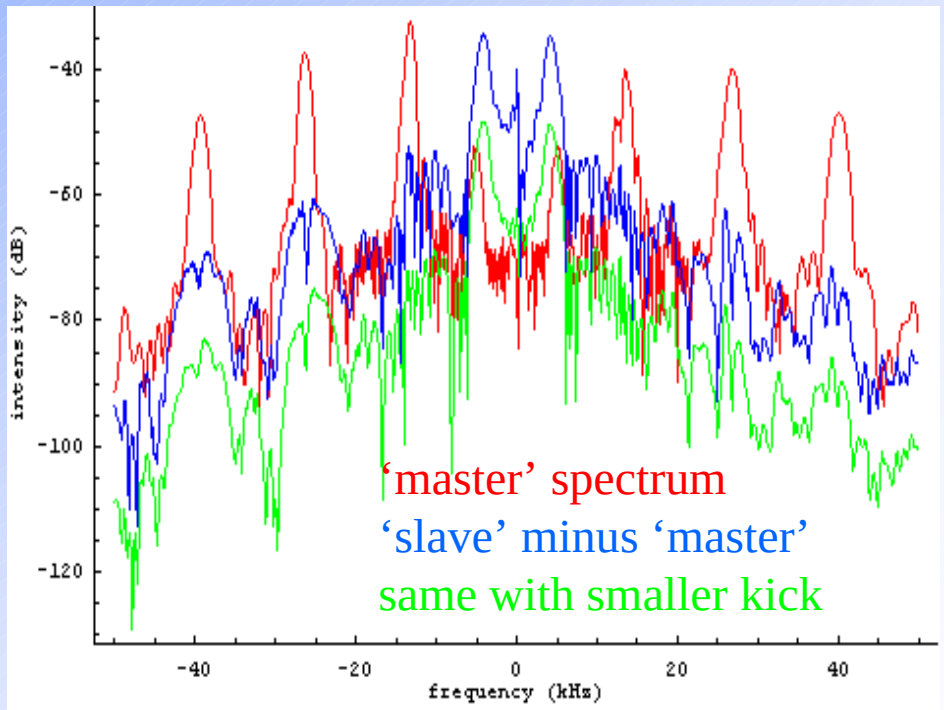
Calculation of beam-response functions

- Beam evolves in response to sine and cosine kicks at kick harmonic
- Fourier transform with respect to time at the response harmonic
- This method assumes that the response of the beam is linear



Slave bunches and coherence of multiple bunches

- **Single-bunch code to look for loss of coherence of multiple bunches due to non-regular motion**
  - Integrate an unstable ‘master’ bunch
  - Apply some kick to a second ‘slave’ bunch and integrate under the influence of the field from the first bunch
  - Compute the difference between spectra
- **Strongest effect expected for stretched and overstretched bunches**



HOM-only impedance, partially stretched bunch
Example does not show significant decoherence